Cartoon Hair Animation Based on Physical Simulation

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Introduction

The hair movement in cel character animation is sometimes inconsistent. The representation of hair, therefore, is a specialized work in cel animation. It is difficult to achieve in computer graphics, since cel animation may not be consistent with all the hair's attributes from all camera positions. In fact, what animators create by solving physics equations is not always what the animators desire even though it is physically correct. Also the motion of hair in cartoon animation carries meaning. Therefore, what the animators want exists only in their imagination, and all the hair forms (shape modeling and number of hairs) in the key frames from the animation sequence cannot be in complete agreement (Fig1). Quite convincing results, however, can be obtained from physically inconsistent frames. This is the most difficult part of expressing cartoon hair animation in computer graphics and is the reason why cartoon hair animation has been done by hand. It requires the instincts of an expert animator – and is very time consuming. In fact, the work of even a skilled animator is highly demanding. Yet there have been little researches[1] directed to the solutions to time-consuming problems such as the cel animation of hair motion.

In this paper, we thus focus on the dynamics of animated hair, particularly as it related to cel animation. Our final goal is to retain the "Anime-Like" aspect of animation while still giving an animator the ability to easily create what is desired by using physical equations. One way to reduce an animator's workload is to consider hair geometry in three dimensions. Although cel animation is a 2-dimensional structure, we consider the cartoon character's 3-dimensional structure in order to create hair motion easily. It is difficult, however, to use 3-dimensional structures to fully express in two dimensions the inconsistencies that are peculiar to animation. Additionally, we propose a method whereby hair animation is done by matching data between 3-dimensional hair models and the key frames of rough sketches made by an animator or director that indicate hair motion. Specifically, we make from the 3-dimensional hair model a hair motion database sequence by using Impulse Force to generate interactive and attractive motion. We try to match the hair data created from rough sketches with 3-dimensional hair database sequence data projected onto the rough sketches. We then make a cartoon hair model to interpolate between the rough sketches.

Original Input and Precomputing

The input to our method is a sparse set of hand-drawn (Fig 1) hair sketches for a cartoon character at corresponding key frames. Our approach is a hybrid one and takes advantages from both key-frame interpolation and physical simulation. The hair sketches reflect the cartoon features we would like to achieve. Therefore, our method requires the preparation of various data before the simulation starts. We first need to prepare a high-quality 2-dimensional cel image of the animated character and the roughly sketched images. These materials are hand-drawn by an animator and are used as original input. A 3-dimensional sparse-hair model is created by obtaining position coordinates and adjusting them in order to extract a hair model that is well adapted for the character animation. Precomputing the motion database[2] is a crucial step in our approach. Because of the sheer number of hair strands and the number of vertices on each strand, building a database with an exhaustive list of configurations would be infeasible. An important contribution of this paper is to build an animator-directed motion database with a chosen set of force impulses that generate sequences that can potentially match the hair sketches. Animator-directed means that the animator can define the direction and magnitude of the impulse force.

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Matching Process: Finding Hair strand From the Database

In order to find the best match hair strand from motion database sequence, our method requires animators to use their intuition to decide camera positions of the rough hair sketches. Thereby, 3-dimensional position points from the hair database sequence are then projected onto the image plane of the rough sketch. (Fig 2) We chose a hair motion sequence that has the smallest error at the key-frames (eq. 1).

$$d_{\min} = \frac{\sum_{i=1}^{k} \|\theta_i - \varphi_i\|}{k} \qquad \|\theta_i - \varphi_i\| < th \qquad (1)$$

Deformation Function for Angles

This interpolation is a linear combination of nonlinear functions of distance from the data points. This step uses the database sequence chosen in the matching process. We apply RBFs to the discrepancies in angles in order to get the desired shape.

Interpolation Between Hair Motions

We interpolate between two consecutive hair sequences in order to connect the hair motion smoothly. Since we define impulse forces to construct the hair motion database, the animation result may not be smooth without interpolation. We use eq. (2) for Interpolation.

$$S = \frac{1}{2}\left(1 + \frac{(1+c)\times(t\times 2-1)}{\|t\times 2-1\|+c}\right) \quad (0 < t < 1) \quad (2)$$

Results

Fig 3 shows a result made from input that requires camera motion. It clearly shows the effectiveness of our method, since there are few animators who can achieve such an animation by hand drawing.

References

[1] Paul Rademacher, View-Dependent Geometry In *Proceedings of SIGGRAPH 99*, L.A pp. 439-446

[2] Doug L. James and Kayvon Fatahalian, Precomputing Interactive Dynamic Deformable Scenes, In Proceedings of ACM SIGGRAPH, 2003.

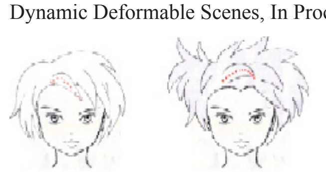

Figure 1: Rough Sletches

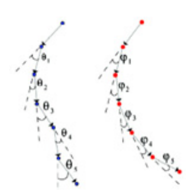

Figure 2: Matching Sample between rough sketch and database data

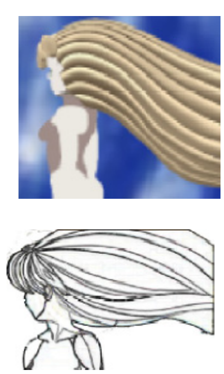

Figure 3: Matching Frame